



Prepared in cooperation with the Massachusetts Office of Coastal Zone Management

# Geophysical and Sampling Data from the Inner Continental Shelf: Duxbury to Hull, Massachusetts

By Walter A. Barnhardt, Seth D. Ackerman, Brian D. Andrews, and Wayne E. Baldwin

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## Conversion Factors

### SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
Area		
square kilometer (km <sup>2</sup> )	247.1	acre
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )

Phi conversion: Particle size in phi units may be converted to millimeters (mm) as follows:  $mm=2^{-\text{phi}}$

Vertical coordinate information is referenced to Mean Lower Low Water (MLLW).

Horizontal coordinate information is referenced to the World Geodetic System of 1984 (WGS 84).

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## Abstract

The U.S. Geological Survey (USGS) and the Massachusetts Office of Coastal Zone Management (CZM) have cooperated to map approximately 200 km<sup>2</sup> of the Massachusetts inner continental shelf between Duxbury and Hull. This report contains geophysical and geological data collected by the USGS on three cruises between 2006 and 2007. These USGS data are supplemented with a National Oceanic and Atmospheric Administration (NOAA) hydrographic survey conducted in 2003 to update navigation charts. The geophysical data include (1) swath bathymetry from interferometric sonar and multibeam echosounders, (2) acoustic backscatter from sidescan sonar and multibeam echosounders, and (3) subsurface stratigraphy and structure from seismic-reflection profilers. The geological data include sediment samples, seafloor photographs, and bottom videos. These spatial data support research on the influence sea-level change and sediment supply have on coastal evolution, and on efforts to understand the type, distribution, and quality of subtidal marine habitats in the Massachusetts coastal ocean.

## Introduction

This report presents high-resolution maps and spatial data for the seafloor offshore of Massachusetts, between Duxbury and Hull (fig. 1). Approximately 200 square kilometers (km<sup>2</sup>) of the inner continental shelf was mapped with a focus on areas inside the 3-mile limit of State jurisdiction. Water depths ranged from 2 to 38 m. The maps are the fourth in a series (Barnhardt and others, 2006, 2009; Ackerman and others, 2006) produced by a cooperative mapping program of the U.S. Geological Survey (USGS) and the Massachusetts Office of Coastal Zone Management (CZM). The marine geophysical data, sediment samples, and bottom photography in this report were obtained during three USGS research cruises in 2006 and 2007, and one National Oceanic and Atmospheric Administration (NOAA) hydrographic survey in 2003 (fig. 2). Existing data, collected by NOAA to update navigation charts in the region, have been used throughout this mapping program to help characterize seafloor geology and morphology whenever possible.

The long-term objectives of this mapping program are to build a foundation for scientific research and to provide geologic information for management of coastal and marine resources. Accurate maps of seafloor geology are important first steps toward protecting fish habitat, delineating marine resources, and assessing environmental changes caused by natural or human impacts. This report documents the data collection and processing methods and provides access to the data. Available datasets include bathymetry, acoustic backscatter intensity, seismic reflection, textural analyses of

sediment samples, and bottom photographs. These data products are integrated within a Geographic Information System (GIS) to form the basis for interpretive geologic maps that will be published for this region and help guide future management decisions.

The inner continental shelf offshore of this section of the Massachusetts coast is a high-relief, glaciated seafloor. The general configuration of the shoreline and inner shelf is controlled by the lithology and structural features of the region's underlying bedrock. Multiple episodes of glacial erosion modified the bedrock framework and deposited unconsolidated sediment to form moraines, drumlins, and other glacial landforms. Following deglaciation, relative sea-level change has been the major process shaping the coast and inner shelf over the last 14,500 years (Oldale and others, 1993). Shoreline transgression and regression have reworked a wide expanse of the inner shelf and largely removed fine-grained sediment from the seafloor in water depths of less than about 50 meters (m). These shallow, nearshore areas are characterized by rugged rock outcrops and relatively thin, discontinuous deposits of coarser grained sediment that ranges in size from sand to gravel and large boulders. Erosion of these glacial deposits provides most of the new sediment that builds beaches and marshes along this stretch of coast.

## Data Collection and Processing

### Bathymetry

Bathymetric data were acquired by the USGS using a Systems Engineering & Assessment Ltd (SEA) SwathPlus 234-kilohertz (kHz) interferometric sonar system at a ping rate of 0.25 seconds (s). During field activity 06012, the transducers were mounted on a rigid pole on the starboard side of the RV *Megan T. Miller* (fig. 3), about 2.6 m below the waterline. A TSS Ltd. Dynamic Motion Sensor (DMS) 2-05 motion reference unit was mounted directly above the sonar transducers and continuously measured vertical displacement (heave) and attitude (pitch and roll) of the vessel during acquisition. During USGS field activity 07001, the transducers were mounted on a rigid pole on the bow of the RV *Rafael*, about 0.5 m below the waterline. A CodaOctopus F-180 inertial-motion unit, mounted directly above the transducers, measured vertical displacement and attitude of the vessel during acquisition. Sound-velocity profiles were collected approximately every 2 hours using a hand-casted Applied MicroSystems SV Plus sound velocimeter. Survey lines were run at an average speed of 5 knots and were spaced 100 m apart to obtain overlapping swaths of data and full coverage of the seafloor. Navigation was based on a Real-Time Kinematic Global Positioning System (RTK-GPS). The RTK-corrected GPS signal was sent to the ship from a base station established by the USGS on land. Soundings were referenced to MLLW using orthometric to chart datum offsets obtained from NOAA Tidal Station #8446009 at Brant Rock Harbor, MA. SEA SwathPlus acquisition software and the Computer Aided Resource Information System (CARIS) Hydrographic Information Processing System (HIPS version 6.1) were used to post-process the raw bathymetric soundings. Navigation data were inspected and edited, soundings were vertically adjusted using corrections from RTK-GPS water-level and sound-velocity profile data, spurious soundings were eliminated, and final processed soundings were gridded at a resolution of 5 m per pixel (fig. 4).

Bathymetric data were collected by NOAA in an area adjacent to the northern boundary of the USGS survey area (fig. 2). Survey launches 1005 and 1014 acquired soundings using hull-mounted RESON SeaBat 8101 and 8125 multibeam-echosounder systems, respectively. The position and attitude of both launches were measured using TSS POS/MV 320 GPS-aided inertial navigation

systems. A Digibar Pro was used on Launch 1014 to continuously measure surface sound-velocity data. Survey lines were spaced between 15 and 50 m apart to obtain overlapping swaths of data and full coverage of the seafloor. Navigation was based on a Global Positioning System (GPS) corrected by U.S. Coast Guard differential GPS (DGPS) beacon No. 771 located at Portsmouth, NH. Tidal corrections were calculated using a discrete tidal zoning model and verified data from tidal station #8443970 at Boston, MA, and final corrected soundings were referenced to MLLW (NOAA DAPR, 2003; NOAA DR, 2003).

The USGS and NOAA swath bathymetric datasets were combined into a single final 5-m per pixel grid, which is available in grid or image format in appendix 1 (Geospatial Data).

## Acoustic Backscatter

Acoustic backscatter data were collected during USGS field activities 06012 and 07001 with a Klein 3000 dual-frequency sidescan sonar (132/445 kHz) that was towed approximately 10 m above the seafloor. Data for most of the survey were acquired over a swath width of 200 m (100 m to either side of vessel) using Klein SonarPro acquisition software (versions 9.6 and 10.0). Beam angle and slant-range distortions were corrected by using Xsonar (version 1.1) and ShowImage (Danforth, 1997). The 132-kHz data from each survey line were mapped at 1 m per pixel resolution in geographic space in Xsonar, imported as raw image files to PCI Geomatica (OrthoEngine version 10.0.3), and combined into a mosaic (fig. 5). The mosaic was exported out of PCI as a georeferenced Tagged Image File Format (TIFF) image for further analysis in ArcGIS.

Acoustic backscatter data from multibeam echosounders were also collected during NOAA hydrographic survey H10993. RESON SeaBat 8101 and 8125 multibeam echosounder systems were hull-mounted on NOAA Ship *Thomas Jefferson* launches 1005 and 1014, respectively. The raw eXtended Triton Format (XTF) multibeam backscatter data from NOAA survey H10993 were processed at the USGS using a radiometric-correction technique developed by the Ocean Mapping Group and the University of New Brunswick (Beaudoin and others, 2002).

GeoTIFF mosaics of backscatter imagery are presented in appendix 1 (Geospatial Data) of this report. The mosaic of USGS data is all derived from Klein 3000 sidescan-sonar backscatter. The mosaic of NOAA data is all derived from multibeam-echosounder backscatter. Due to acquisition and processing differences, these images were not combined into a single mosaic but can be used independently to define seafloor character and morphology.

## Seismic-Reflection Profiling

### Seismic-Reflection Data Acquisition 06012

Chirp seismic data were collected using an EdgeTech Geo-Star FSSB sub-bottom profiling system and an SB-0512i towfish, which was mounted on a catamaran and towed astern of the RV *Megan T. Miller*. EdgeTech J-Star seismic acquisition software was used to control the Geo-Star topside unit and digitally log trace data in the EdgeTech JSF format. Data were acquired using a 0.25-second (s) shot rate, a 9-millisecond (ms) pulse length, and a 0.5 to 6 kHz frequency sweep. Recorded trace lengths were approximately 266 ms. Tracklines were spaced between 100 and 200 m apart in the shore-parallel direction and between 1 and 3 km apart in the shore-perpendicular direction.

## Seismic-Reflection Data Acquisition 07001

Chirp seismic data were collected using an EdgeTech Geo-Star FSSB sub-bottom profiling system and an SB-424 towfish, which was mounted on a rigid pole on the starboard side of the RV *Rafael*. EdgeTech J-Star and Triton Imaging Inc. SB-Logger seismic acquisition software were used to control the Geo-Star topside unit and digitally log trace data in EdgeTech JSF and SEG-Y Rev. 1 formats, respectively. Data were acquired using a 0.25-s shot rate, a 10-ms pulse length, and a 4 to 16 kHz frequency sweep. Recorded trace lengths were approximately 250 ms. Tracklines were spaced 100 m apart in the shore-parallel direction and between 200 m and 2 km apart in the shore-perpendicular direction.

Raw seismic data were post-processed with SIOSEIS (Scripps Institution of Oceanography) and Seismic Unix (Colorado School of Mines). JPEG images of the chirp profiles are included in appendix 1 (Geospatial Data) of this report. Navigation and processed SEG-Y data were imported into SeisWorks 2D (Landmark Graphics, Inc.) for digital interpretation.

## Ground Validation

### Surficial Sediment Samples and Grain-Size Analyses

Surficial sediment samples were acquired during USGS field activity 07003 (RV *Connecticut*; September 7-11, 2007) at 28 of the 77 SEABed Observation and Sampling System (SEABOSS) locations to validate the geophysical data (fig. 5). Sediment samples were usually collected at the end of each camera tow, and samples were not collected in rocky areas. The upper 2 centimeters (cm) of sediment were bagged and taken to the USGS sediment laboratory for grain-size analysis. Grain-size analyses were completed using procedures outlined by Poppe and others (2005). These data include information regarding sample location, bulk weight, percent of sample in each 1-phi size class from -5 phi to 11 phi, sediment classification, kurtosis, and other sediment-related statistics. These data are available in spreadsheet or geospatial format in appendix 2 (Textural Analyses).

### Photography and Video

High-resolution digital photographs and video of the seafloor were collected at all 77 locations within the study area. At each station, the USGS SEABOSS (Valentine and others, 2000) (fig. 6) was towed over the bottom at speeds of less than 1 knot. Because the recorded position is actually the position of the GPS antenna on the survey vessel, not the SEABOSS sampler, the estimated horizontal accuracy of the sample location is  $\pm 30$  m. Photographs were obtained from a digital still camera, and continuous video was collected, usually for 5 to 15 minutes. Digital bottom photographs are available as JPEG images in appendix 3 (Bottom Photographs). Continuous video data are not included in this report but may be available upon request.

## Acknowledgments

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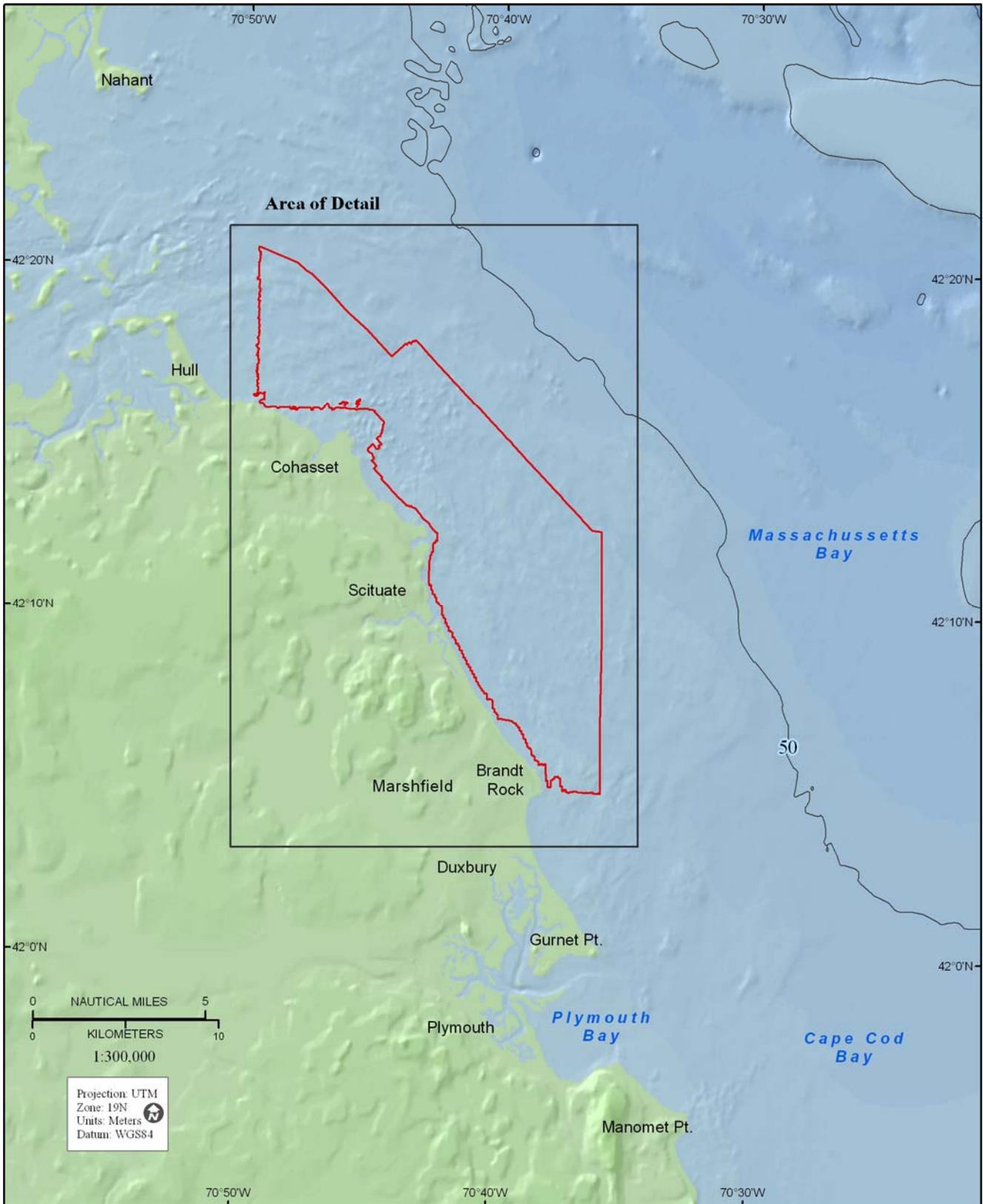
## References Cited

- Ackerman, S.D., Butman, Bradford, Barnhardt, W.A., Danforth, W.W., and Crocker, J.M., 2006, High-resolution geologic mapping of the inner continental shelf; Boston Harbor and Approaches, Massachusetts: U.S. Geological Survey Open-File Report 2006-1008, 1 DVD. (Also available at <http://pubs.usgs.gov/of/2006/1008/>.)
- Barnhardt, W.A., Andrews, B.D., and Butman, Bradford, 2006, High-resolution geologic mapping of the inner continental shelf; Nahant to Gloucester, Massachusetts: U.S. Geological Survey Open-File Report 2005-1293, 1 DVD. (Also available at <http://pubs.usgs.gov/of/2005/1293/>.)
- Barnhardt, W.A., Andrews, B.D., Ackerman, S.D., Baldwin, W.E., and Hein, C.J., 2009, High-resolution geologic mapping of the inner continental shelf; Cape Ann to Salisbury Beach, Massachusetts: U.S. Geological Survey Open-File Report 2007-1373, 1 DVD. (Also available at <http://pubs.usgs.gov/of/2007/1373/>.)
- Beaudoin, J.D., Hughes-Clarke, J.E., van den Aemele, E.J., and Gardner, J.V., 2002, Geometric and radiometric correction of multibeam backscatter derived from RESON 8101 systems: Canadian Hydrographic Conference Proceedings, 1 CD-ROM. (Also available at [http://www.omg.unb.ca/omg/papers/Beaudoin\\_Multibeam\\_Backscatter\\_Reson\\_8101\\_Systems.pdf](http://www.omg.unb.ca/omg/papers/Beaudoin_Multibeam_Backscatter_Reson_8101_Systems.pdf))
- Danforth, W.W., 1997, Xsonar/ShowImage; a complete system for rapid sidescan sonar processing and display: U.S. Geological Survey Open-File Report 97-686, 77 p.
- NOAA DAPR, 2003, National Oceanic and Atmospheric Administration Data Acquisition and Processing Report, NOAA Ship Thomas Jefferson (August - November 2003), Massachusetts Bay, Massachusetts: National Oceanic and Atmospheric Administration, National Geophysical Data Center (NGDC), Boulder, CO. (Available at <http://surveys.ngdc.noaa.gov/mgg/NOS/DAPRs/NOAAShipTHOMASJEFFERSONAugNov2003.pdf>)
- NOAA DR, 2003, National Oceanic and Atmospheric Administration Descriptive Report, Basic Hydrographic Survey H10993, Approaches to Boston Harbor, Massachusetts Bay, Massachusetts: National Oceanic and Atmospheric Administration, National Geophysical Data Center (NGDC), Boulder, CO. (Available at <http://surveys.ngdc.noaa.gov/mgg/NOS/coast/H10001-H12000/H10993/DR/H10993.pdf>)

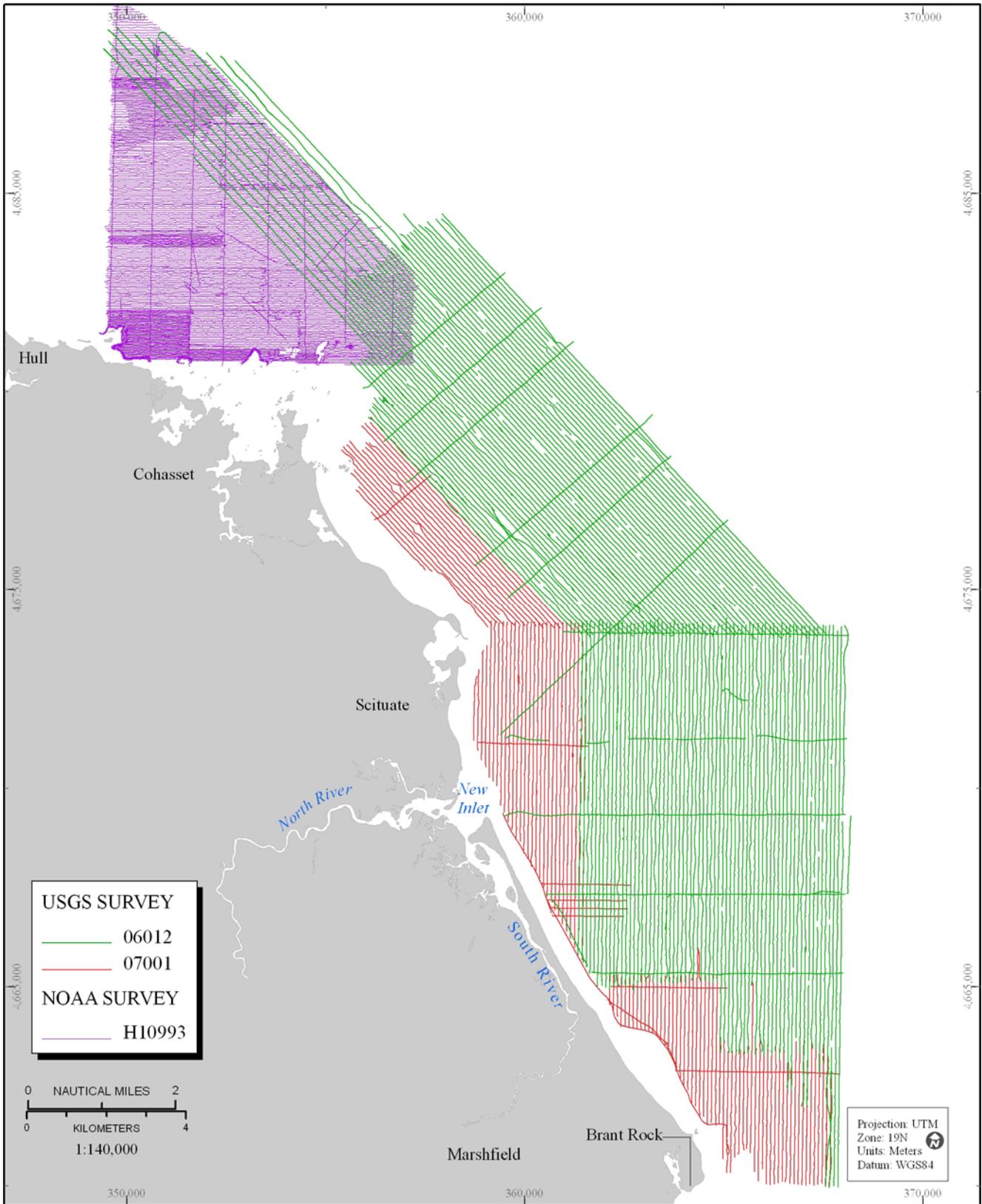
Oldale, R.N., Colman, S.M., and Jones, G.A., 1993, Radiocarbon ages from two submerged strandline features in the western Gulf of Maine and a sea-level curve for the northeastern Massachusetts coastal region: *Quaternary Research*, v. 40, p. 38–45.

Poppe, L.J., Williams, S.J., and Paskevich, V.F., eds., 2005, USGS East-Coast Sediment Analysis; Procedures, Database, and GIS Data: U.S. Geological Survey Open-File Report 2005–1001, 1 DVD ROM. (Also available online at <http://pubs.usgs.gov/of/2005/1001/>.)

Valentine, Page, Blackwood, Dann, and Parolski, Ken, 2000, Seabed Observation and Sampling System: U.S. Geological Survey Fact Sheet FS 142-00, 2 p. (Also available at <http://pubs.usgs.gov/fs/fs142-00/>.)



**Figure 1.** Map showing the location of the survey area (outlined in red) offshore of eastern Massachusetts between Duxbury and Hull. The 50-meter depth contour is shown. Black rectangle indicates area of detail shown in figures 2, 3, and 4.



**Figure 2.** Map showing tracklines of geophysical data collected by USGS (red and green lines) and NOAA (purple lines). USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration.



Figure 3. Photographs of research vessels used for mapping surveys in this project. A, RV *Megan T. Miller*; B, RV *Rafael*; C, RV *Connecticut*; D, RV *Thomas Jefferson*.

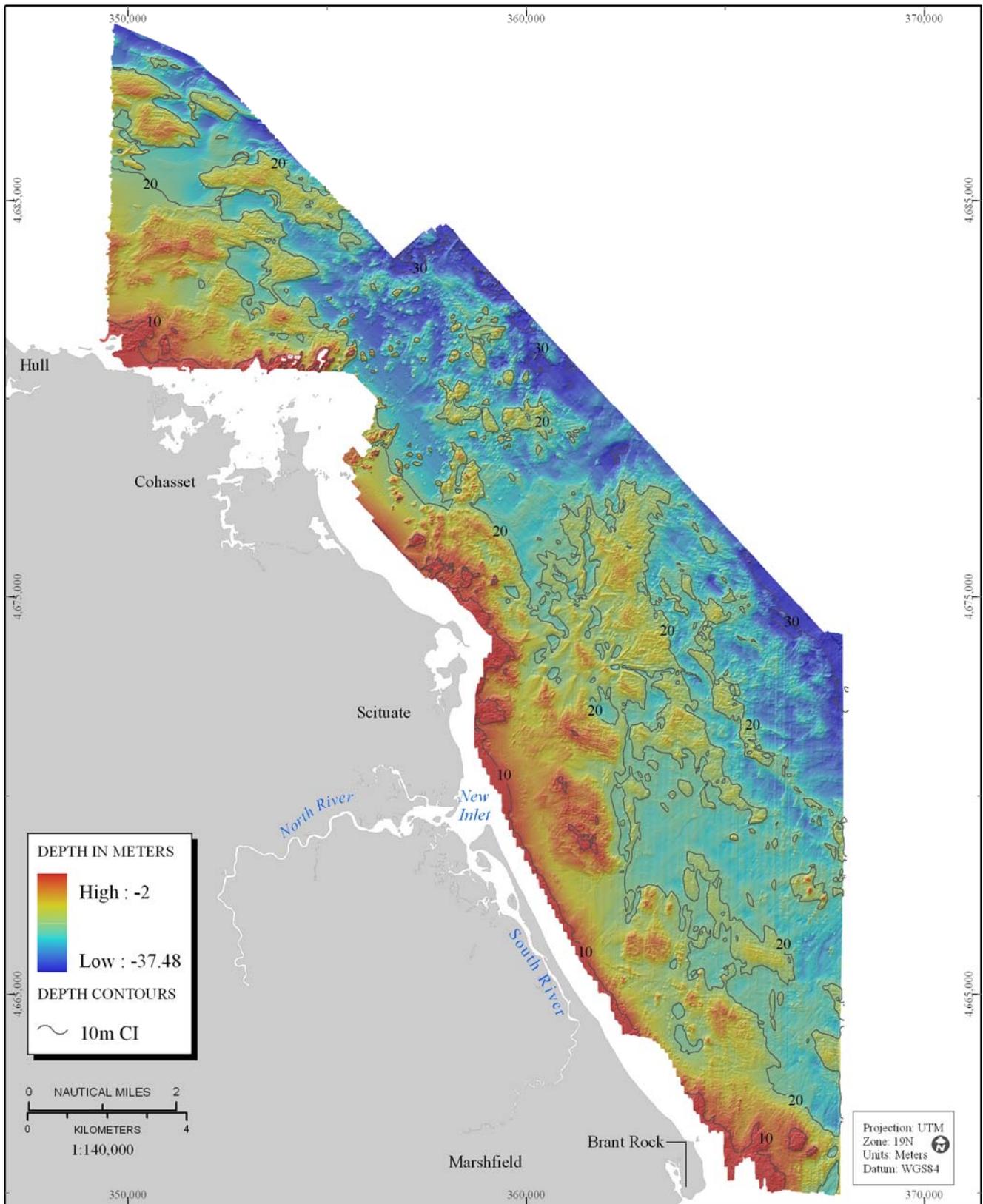
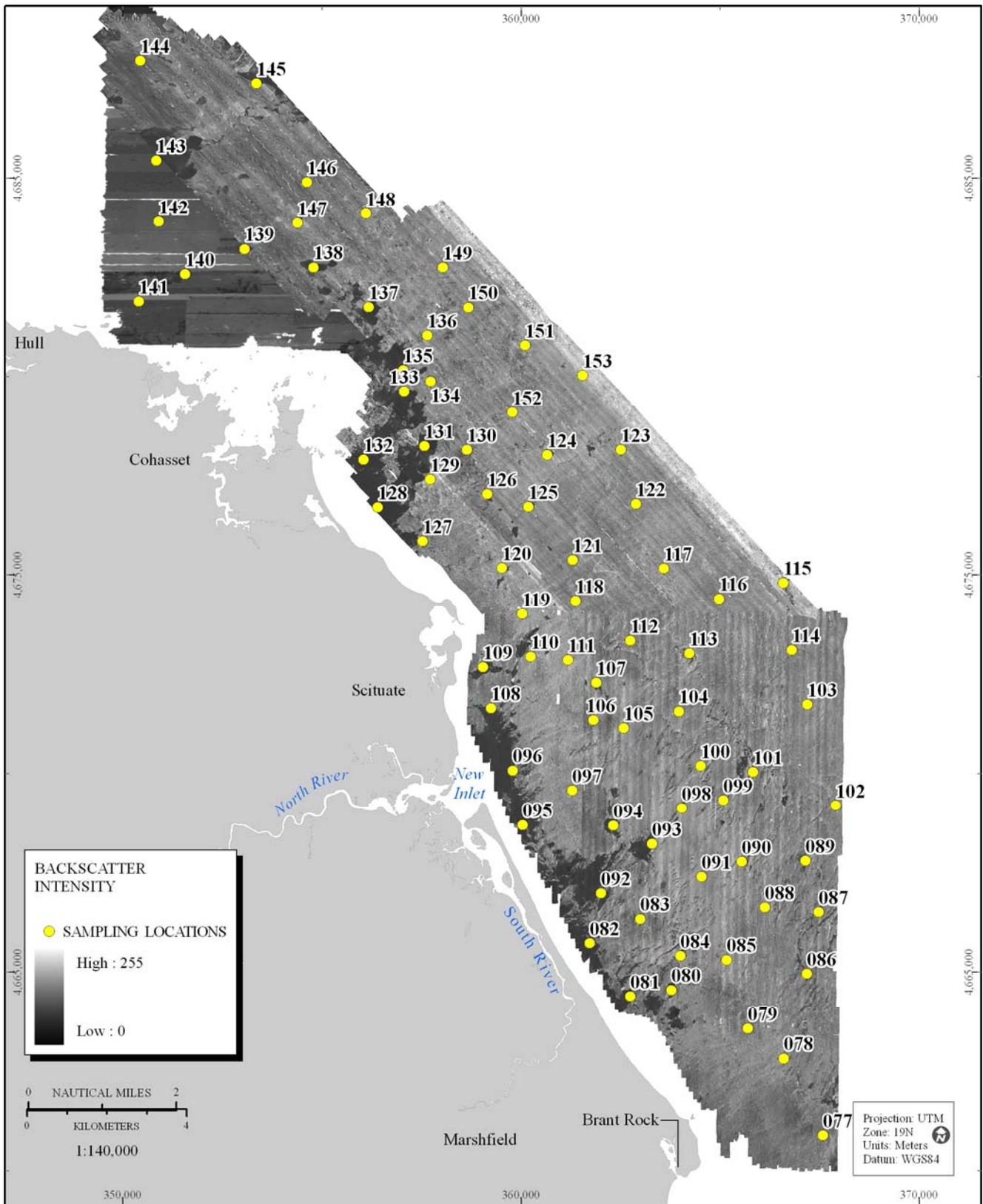


Figure 4. Map showing shaded-relief topography of seafloor in study area. Coloring and bathymetric contours represent depths in meters, relative to the local Mean Lower Low Water (MLLW) datum.



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